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Appeal
Brief
8/27/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
Before the Board of Patent Appeals and Interferences

In re Patent Application of

HERBERT et al — Atty. Ref.: 124-850

Serial No. 09/807,515 — Group: 2811

Filed: April 16, 2001 — Examiner: D. Kang

For: IMPROVEMENTS IN IMPATT DIODES

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APPEAL BRIEF

On Appeal From Group Art Unit 2811

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I. REAL PARTY IN INTEREST

The real party in interest in the above-identified appeal is **QINETIQ LIMITED**, by virtue of the Assignment from the Secretary of State for Defence recorded February 20, 2002, at Reel 12831, Frame 459 and a previous assignment from the inventors to the Secretary of State for Defence recorded April 16, 2001 Reel 11762, Frame 841.

II. RELATED APPEALS AND INTERFERENCES

There are believed to be no related appeals or interferences with respect to the present application and appeal.

III. STATUS OF CLAIMS

Claims 1 through 19 stand rejected in the outstanding Final Rejection. The Examiner contends that claims 1 through 19 are either anticipated under 35 USC §102 or obvious under 35 USC §103 in view of the cited prior art

IV. STATUS OF AMENDMENTS

No further response has been submitted with respect to the Final Official Action in this application.

V. SUMMARY OF THE INVENTION

The present invention relates to impact ionization avalanche transit time (IMPATT) diodes which are a semi-conductor structure which produce negative resistance at microwave frequencies.

Conventionally the IMPATT diode consists of heavily doped contact regions separated by a depleted region with a doping profile designed to produce an avalanche region and a drift region. While conventional IMPATT diodes are extremely powerful solid-state sources of microwave power, such diodes are conventionally noisy and sensitive to operating conditions.

The noise in a conventional IMPATT diode arises mainly from the statistical nature of the generation rates of electron-whole pairs at or above the breakdown voltage. Conventionally noise from an IMPATT diode can be reduced somewhat by operating the diode well above the resonant frequency of the diode and keeping the current low. Unfortunately these conditions conflict with conditions favoring high power output and efficiency.

Applicant found that, contrary to conventional wisdom, if a narrow bandgap region is located adjacent to the main avalanche region, a tunnel current can be generated within the narrow bandgap region which is injected into the main avalanche region in a predictable manner. Applicant found that this current pulse injected into the main avalanche region maintains high power output while

providing a low noise avalanche. As a result of the present invention, high power IMPATT diode devices can be constructed which provide relatively low noise output.

The present invention comprises "**a main avalanche region**", and "**a drift region**" and a "**small bandgap region**" (bandgap narrower than the main avalanche region) which is "**located adjacent to the main avalanche region in order to generate within the narrow band gap region a tunnel current which is injected into the main avalanche region.**"

VI. ISSUES

Whether claims 1 through 8, 10 and 13 through 15 are anticipated by Meng et al. (U.S. patent 5, 466,965).

Whether claims 9, 11 and 12 are obvious under 35 U.S.C. § 103 over Meng in view of Mishra (cited as reference U).

Whether claims 17 through 19 are obvious under 35 U.S.C. § 103 as unpatentable over Meng.

VII. GROUPING OF CLAIMS

The rejected claims do not stand or fall together and are independently patentable as described in the argument portion of this Appeal Brief.

VIII. ARGUMENT

1. Discussion of the References

Meng (U.S. patent 5,466,965) teaches a conventional high power high efficiency IMPATT diode device which is typical of the prior art discussed in the background of applicants' invention in the originally submitted application.

As is well known in the art, the avalanche region of an IMPATT diode is the region where **carrier multiplication occurs through avalanche ionization** (see applicants' specification page 1, lines 14-16). The Examiner suggests that region 18 of Meng is a "main avalanche region" where significant ionization occurs. However, Meng clearly states in column 5, lines 39 through 43 that layer 18 "is considered a barrier layer." Meng also states that the barrier layer operates to accelerate the current carrier to "a higher energy **without impact ionization** and energy relaxation in barrier region 18." (emphasis added - column 5, lines 48 to 50). In other words, Meng teaches that no ionization takes place in layer 18, which the Examiner concludes is the "main avalanche region."

Thus while Meng is a conventional IMPATT diode device, there is no support for the allegation that Meng teaches that layer 18 is an avalanche region or that narrow bandgap region generates a tunnel current.

Mishra et al (Design Optimization Of A Single-Sided Si/SiGe Heterostructure" Reference U cited for the first time in the final rejection) is

alleged to teach an IMPATT diode having double drift regions for the purpose of obtaining better millimeter properties and lower noise. Additionally Mishra is cited for allegedly teaching an IMPATT diode comprised of Si/SiGe heterostructure.

There appears to be no organizational inter relationship in Mishra which places a narrow bandgap region adjacent a main avalanche region in order to generate within the narrow bandgap region a tunnel current which is injected into the main avalanche region.

2. Discussion of the Rejections

Claims 1 through 8, 10 and 13 through 15 stand rejected under 35 U.S.C. §102 as being anticipated by Meng. To the extent the Examiner's rejection is understood, the Examiner apparently believes that the subject matter of each of these claims is shown in the Meng reference. The Examiner specifically alleges that Meng teaches a main avalanche region 18 a drift region 20 and a narrow bandgap region 16.

Claims 9, 11 and 12 stand rejected under 35 U.S.C. § 103 as being unpatentable over Meng in view of Mishra. The Examiner admits that Meng fails to teach "the diode is a double drift diode" and that Meng fails to teach "the diode is made of group IV semiconductor materials." To the extent the rejection is understood, the Examiner apparently believes that Mishra contains the missing

teaching. Presumably the Examiner also believes that there is inherently some reason for combining the Meng and Mishra references (although the Examiner fails to identify any reason or motivation for combining the references in the final rejection).

Claims 17 through 19 stand rejected under 35 U.S.C. § 103 as being unaptentable over Meng. The Examiner's admission that Meng "do not expressly teach an oscillating voltage across the diode having a period of between four and twelve time the transit time of the avalanche region" is very much appreciated. To the extent the rejection is understood, the Examiner appears to believe that noise properties of a diode can be improved by optimization and that it would somehow be obvious to vary the oscillating voltage in order to obtain a desired device. There is no indication of how or why the specifics of the oscillating voltage would be obvious nor is there any citation of a reference containing such a teaching.

3. The Errors in the Final Rejection

There are at least four significant errors in the Final Rejection and they are summarized as follows:

(a) No prior art reference teaches or suggests generation of "a tunnel current which is injected into the main avalanche region" of an IMPATT diode device;

(b) There is no reason or suggestion for combining the Meng and Mishra references;

(c) Meng actually teaches away from the claimed combination of elements; and

(d) There is no teaching of the dependent claim limitations in the cited prior art.

(a) No prior art reference teaches or suggests generation of "a tunnel current which is injected into the main avalanche region" of an IMPATT diode device

Applicants' independent claim 1 provides a benefit over the prior art in that it provides an IMPATT diode device which retains the power and efficiency of prior art devices but does so with a significantly lowered noise component.

The structure which provides this unexpected and beneficial result is the organization of the main avalanche region, a drift region and a narrow bandgap region. Specifically the "narrow bandgap region" is located "adjacent the main avalanche region" so as to generate, in the narrow bandgap region, "a tunnel current" which is injected into the main avalanche region. It is this tunnel current which provides the higher efficiency and higher power while at the same time reducing noise from the diode output.

As applicant previously noted in the Amendment filed December 30, 2002 (see pages 8 and 9) the Examiner contends that Meng's main avalanche region is

item 18. Yet this is clearly incorrect as Meng states that "the aluminum gallium arsenide layer 18 is considered a barrier layer . . . ." (column 5, lines 39 to 41). Meng goes on to state that impact ionization **does not occur** within the barrier region 18 to any substantial extent ("the width of the barrier is not so great that impact ionization can occur to any substantial extent within barrier region 18." column 5, lines 43 to 45). Thus the entire premise of the Examiner's rejection i.e., that Meng teaches a main avalanche region 18, is simply incorrect.

An examination of Meng's Figure 2 will show that, if the drift region is item 20, and the avalanche region is 14 (as stated in column 3, line 53) then the only layer or region adjacent to the avalanche region is buffer 24 (see Figure 2). There is no indication that buffer 24 comprises a narrow bandgap region or provides a tunnel current which is injected into the main avalanche region.

Because these structures and structural inter relationships are positively recited in applicants' independent claim 1 and are missing from the Meng reference, there is simply no support for the Examiner's rejection of claim 1 based upon the Meng reference.

The Examiner has not alleged that any of the above missing structures or structural inter relationships have been supplied by the Mishra reference. While specific structures are shown in Mishra, there is no suggestion that they be combined in the IMPATT diode device of applicants' claims.

Accordingly, there is no support anywhere in the outstanding final rejection for any of claims 1 through 8, 10 and 13 through 15 being anticipated by Meng or for claims 9, 11, 12, and 17 through 19 being obvious in view of Meng by itself or when combined with Mishra. The claimed subject matter simply is not present in the claimed subject matter of claim 1 from which all dependent claims depends is simply not present in either of these two prior art references.

(b) There is no reason or suggestion for combining the Meng and Mishra references

The Examiner combines the Meng and Mishra references with respect to the rejection of claims 9, 11 and 12. While the Examiner admits that the structures claimed in claims 9, 11 and 12 are not present in the Meng reference, the Examiner suggests that such structures are disclosed in the Mishra reference **and** that it would be obvious to one of ordinary skill in the art to combine the two references. The Examiner fails to provide any support for his contention of obviousness.

There is simply no stated reason for modifying or combining the Mishra reference with the disclosure in Meng. The burden is on the Examiner to establish a *prima facie* case of obviousness and the Examiner has simply failed to meet this burden. Accordingly, any future rejection of claims 9, 11, 12 and 17 through 19 under the provisions of 35 U.S.C. § 103 either in view of the Meng/Mishra combination or Meng by itself is respectfully traversed.

(c) Meng actually teaches away from the claimed combination of elements

Not only does the Meng reference fail to teach the claimed subject matter or applicants' independent claim 1 and claims dependent thereon, Meng would actually lead one of ordinary skill in the art away from applicants' claimed invention. As discussed in column 6, lines 25 to 45, Meng teaches that, in order to provide high power low noise in the Meng device, it is necessary to illuminate the avalanche region by laser 34. Applicants' claimed invention provides a high power low noise impact diode device by providing the claimed narrow band gap region which is "located adjacent to the main avalanche region" and is used to "generate within the narrow bandgap region a tunnel current which is injected into the main avalanche region." In Meng, there is no mention of any tunnel current being injected into the main avalanche region and instead Meng clearly teaches away from that with its optical injection energy.

Thus Meng would clearly lead one of ordinary skill in the art away from applicants' claimed combination of elements.

(d) There is no teaching of the dependent claim limitations in the cited prior art

While applicants' dependent claims 2 through 19 all ultimately depend from claim 1 and are thus patentable over the Meng and Mishra references in view of

that dependency, each of these claims also adds limitations which are clearly not anticipated or obvious in view of the cited prior art references.

Regarding claim 2 and its requirement that the narrow bandgap region generates the injected tunnel current "at the peak reverse bias voltage applied to the diode." the Examiner fails to point out how or where this is disclosed in the Meng reference.

With respect to the recitation in claim 3 that the narrow band gap region is located at the edge of the main avalanche region, the Examiner fails to identify either the narrow bandgap region or the main avalanche region or any figure in Meng which shows this claimed inter relationship.

With respect to claim 4 reciting that the narrow band gap region is located between a heavily doped contact region and a main avalanche region the Examiner merely states this conclusion is disclosed in Meng. While the Examiner identifies the "heavily doped contact region (24)," it can be seen in Figure 2 that there is no region located between region 24 and region 14 which is identified as the avalanche region. Thus Meng fails to support the Examiner's contention.

With respect to claim 5 the Examiner merely copies the language of claim 5 but fails to identify any structure or organization of structures in Meng which teaches that the narrow bandgap region comprises one layer of narrow bandgap material.

Regarding claim 6, the Examiner again merely copies the language of claim 6 but does not identify any structure which allegedly shows that any structuring which shows that the narrow bandgap region comprises a plurality of layers of narrow band gap material. Similarly with the doping profile of claim 7 the Examiner merely alleges that this present in Meng but fails to identify where or how. Regarding the IMPATT diode being a Misawa p-i-n diode, the Examiner fails to make this allegation or indicate where or how this is shown in the Meng reference.

The Examiner merely alleges that the subject matter of claim 10 is present in Meng but fails to disclose how or where this material is shown. He also fails to show how or where there is any teaching in Meng of the diode of claim 1 being made of the recited materials.

Regarding claim 13 the Examiner alleges that the claimed materials are shown in Meng. However, the Examiner's arguments are inconsistent with his previous pronouncements applicants independent claim recites that there is a narrow bandgap region located adjacent the main avalanche region. Meng teaches a main avalanche region 14 but fails to disclose any "narrow bandgap region" located adjacent thereto. The Examiner refers to gallium arsenide and aluminum gallium arsenide quantum wells 16 and barrier layers 18 but provides no disclosure of the claimed main avalanche region with the adjacent narrow bandgap region.

The Examiner suggests that with respect to claims 14 and 15 the length of the drift region in Meng is between two and six times or 3.5 and 4.5 times the length of the avalanche region and cites column 3, line 50 through column 4, line 15. However, the Examiner is mistaken as Meng at column 3, line 50 begins its discussion with the use of diamond material as a heat sink goes on to a discussion of gallium arsenide and aluminum gallium arsenide but contains no disclosure of the length of the drift region being between two and six times the length of the avalanche. Applicant can find no such comparison or indication in the Meng reference.

Claim 16 specifies the diode of claim 1 in which part of the tunnel current can be generated by optical excitation. Meng teaches that all tunnel current is generated by optical excitation and therefore does not need applicants' claimed narrow bandgap region.

In view of the above, the Examiner's mere recitation of the structural requirements of applicants' dependent claims does not mean that there is any support for those limitations contained in the Meng reference. Should the Examiner continue to suggest that these claimed structures and structural inter relationship are disclosed by Meng, he should identify specifically where they are disclosed by column and line number or appropriate reference to the figures.

With respect to alleged obvious claims 9, 11, 12 and 17 through 19, applicants have previously addressed the objection to claims 9, 11 and 12. Neither Meng nor Mishra teach or suggest any reason for combining the two references. The Examiner's conclusion that it would be obvious to combine the two references does not satisfy the Court of Appeals for the Federal Circuit requirement of the Examiner to show some "reason" or "motivation for combining references." As a result there is simply no support for the rejection of these claims.

Similarly with respect to claims 17 through 19 the Examiner admits that Meng does "not expressly teach an oscillating voltage across the diode having a period of between four and twelve times the transit time of the avalanche region." This admission is appreciated. However, instead of indicating where this operational inter relationship is disclosed or somehow inherent in the skill of one having ordinary skill in the art, the Examiner talks about the benefits reduced noise and concludes that in order to reduce noise it will be obvious to modify the Meng device. Applicants has previously traversed this contention as clearly failing to disclose in any reference or prior art of record a feature which the Examiner admits is not present in the single cited reference. Thus the Examiner has failed to meet his burden of establishing a *prima facie* case of obviousness. Accordingly, any further rejection of claims 17 through 19 is respectfully traversed.

IX. CONCLUSION

The Examiner alleges that all structures recited in applicants independent claim are shown in the Meng reference. Yet, upon detailed examination, the structures and in particular the claimed structural inter relationships are simply missing, both in Meng and in the secondary reference Mishra. The Examiner in his obviousness rejections has failed to provide any motivation or reason for combining the Meng and Mishra references. The Examiner also apparently fails to appreciate that the Meng reference actually teaches away from applicants' claimed combination of elements in which a narrow bandgap region is located adjacent to the main avalanche region. Finally, while the Examiner specifically rejects each of the dependent claims, he fails to point out where or how there is any teaching in either the Meng or Mishra references of the structures or inter relationships recited in those dependent claims.

Thus, and in view of the above, the rejection of claims 1 through 19 over the cited prior art is clearly in error and reversal thereof by this Honorable Board is respectfully requested.

Respectfully submitted,

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SCS:pc
Enclosures
Appendix A – Claims on Appeal

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APPENDIX A

Claims on Appeal

1. An impact ionisation avalanche transit time (IMPATT) diode device comprising:

a main avalanche region;

a drift region; and

a narrow bandgap region with a bandgap narrower than the bandgap in the main avalanche region which narrow bandgap region (4, 40) is located adjacent to the main avalanche region in order to generate within the narrow bandgap region a tunnel current which is injected into the main avalanche region.

2. An IMPATT diode according to claim 1 wherein the narrow bandgap region is arranged to generate a tunnel current for injection into the main avalanche region at the peak reverse bias voltage applied to the diode.

3. An IMPATT diode according to claim 1 wherein the narrow bandgap region is located at the edge of the main avalanche region.

4. An IMPATT diode according to claim 1, wherein the narrow bandgap region is located between a heavily doped contact region and the main avalanche region.

5. An IMPATT diode according to claim 1, wherein the narrow bandgap region comprises one layer of narrow bandgap material.

6. An IMPATT diode according to claim 1, wherein the narrow bandgap region comprises a plurality of layers of narrow bandgap material.

7. An IMPATT diode according to claim 1, wherein the diode has a lo-hi-lo doping profile.

8. An IMPATT diode according to claim 7 wherein the diode is a Misawa p-i-n diode.

9. An IMPATT diode according to claim 1, wherein the diode is a double drift diode.

10. An IMPATT diode according to claim 1, wherein the diode is made of III-V semiconductor materials.

11. An IMPATT diode according to claim 1, wherein the diode is made of group IV semiconductor materials.

12. An IMPATT diode according to claim 11 wherein the narrow bandgap region is made of at least one layer of Silicon Germanium and the main avalanche region is made of Silicon.

13. An IMPATT diode according to claim 10 wherein the narrow bandgap region is made of at least one layer of Gallium Arsenide and the main avalanche region is made of Aluminium Gallium Arsenide.

14. An IMPATT diode according to claim 1, wherein the length of the drift region or regions is between 2 and 6 times the length of the avalanche region.

15. An IMPATT diode according to claim 14 wherein the length of the drift region or regions is between 3.5 and 4.5 times the length of the avalanche region.

16. An IMPATT diode according to claim 1, arranged such that at least part of the tunnel current can be generated by optical excitation.

17. A method of operating the IMPATT diode of claim 1, wherein an oscillating voltage across the diode has a period of between 4 and 12 times the transit time of the avalanche region.

18. A method according to claim 17 wherein the oscillating voltage has a period of between 7.5 and 8.5 times the transit time of the avalanche region.

19. A method according to claim 17 including the step of optically exiting at least part of the tunnel current.